Mars Mission Scenario: Data Volume & PDT Notes

Hamid Hemmati
A. Biswas, S. Piazzolla & S. Townes

OLSG Face-to-Face
18 April 2012

OBJECTIVE

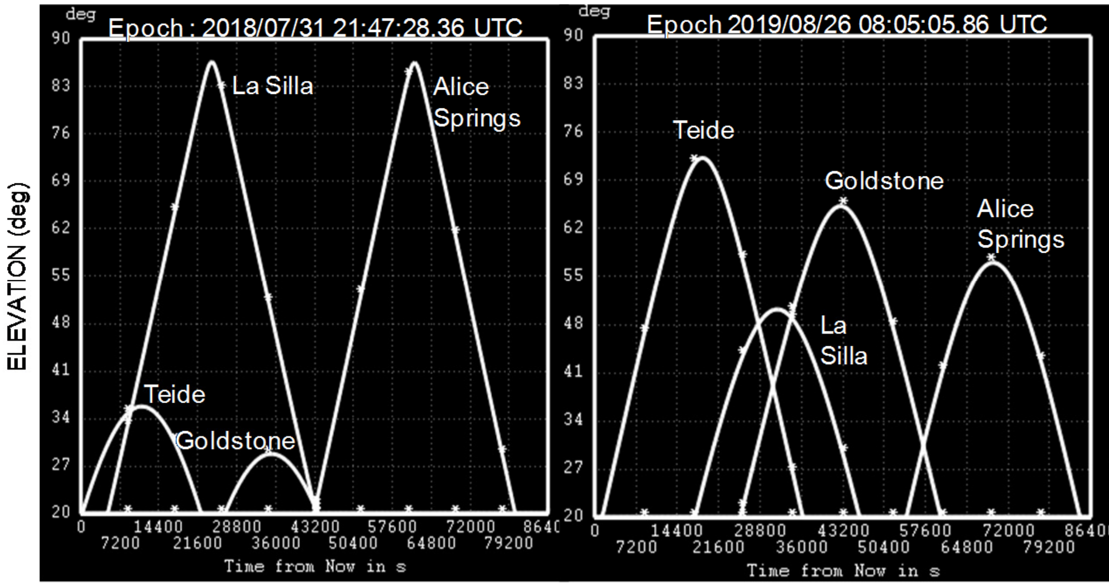
- Investigate methods for quantifying the value of interoperability for deep space missions
  - A network of optical receive stations
    - Each one potentially owned by a different space agency
    - Reduces overall cost to any individual agency
  - Provides geographically diverse locations to mitigate weather problems (clouds, wind, rain, dust, etc.)
- Metrics
  - Total data volume returned over mission duration
  - Percent data transferred (PDT) or something similar

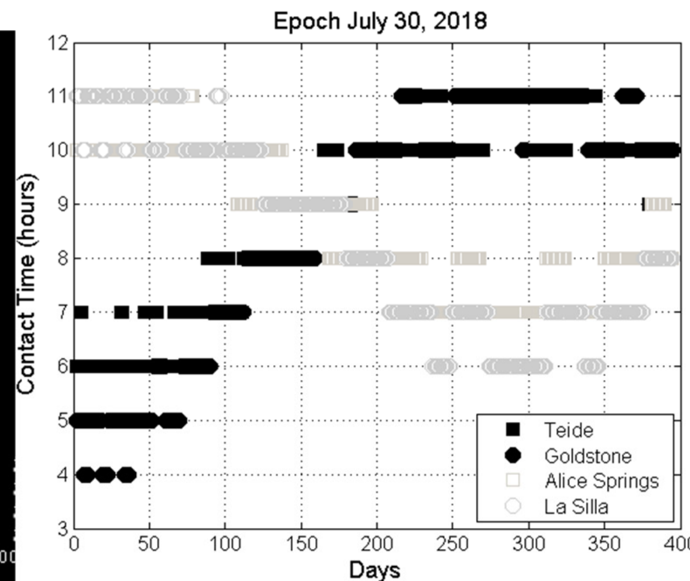
TYPICAL SCENARIO

- Deep space missions are typically designed to return a specified volume of science data over the primary mission duration
  - Mission designers look at the trajectories of Mars and Earth over this time span
  - Passes at Deep Space Communication Complexes (DSCC) are picked to achieve the desired data volume return
    - Relative Earth-Mars geometry varies so no one DSCC will be prime—i.e., use Goldstone (GDSCC) or Madrid (MDSCC) when Mars has good northern hemisphere visibility and Canberra (CDSCC) when Mars is more southerly
  - Data volume returned during a pass, will be a function of data rate (function of range and atmosphere) and pass duration (function of max elevation angle to selected DSCC)

EXAMPLE CONTACT TIMES & CFLOS

- Contact time increases as the number of ground sites increases
  - Northern and Southern hemisphere sites complement each other
- Availability (joint CFLOS) increases during overlapping line-of-sight from 2- or 3-sites





Summary of CFLOS availability of single, two or three ground sites

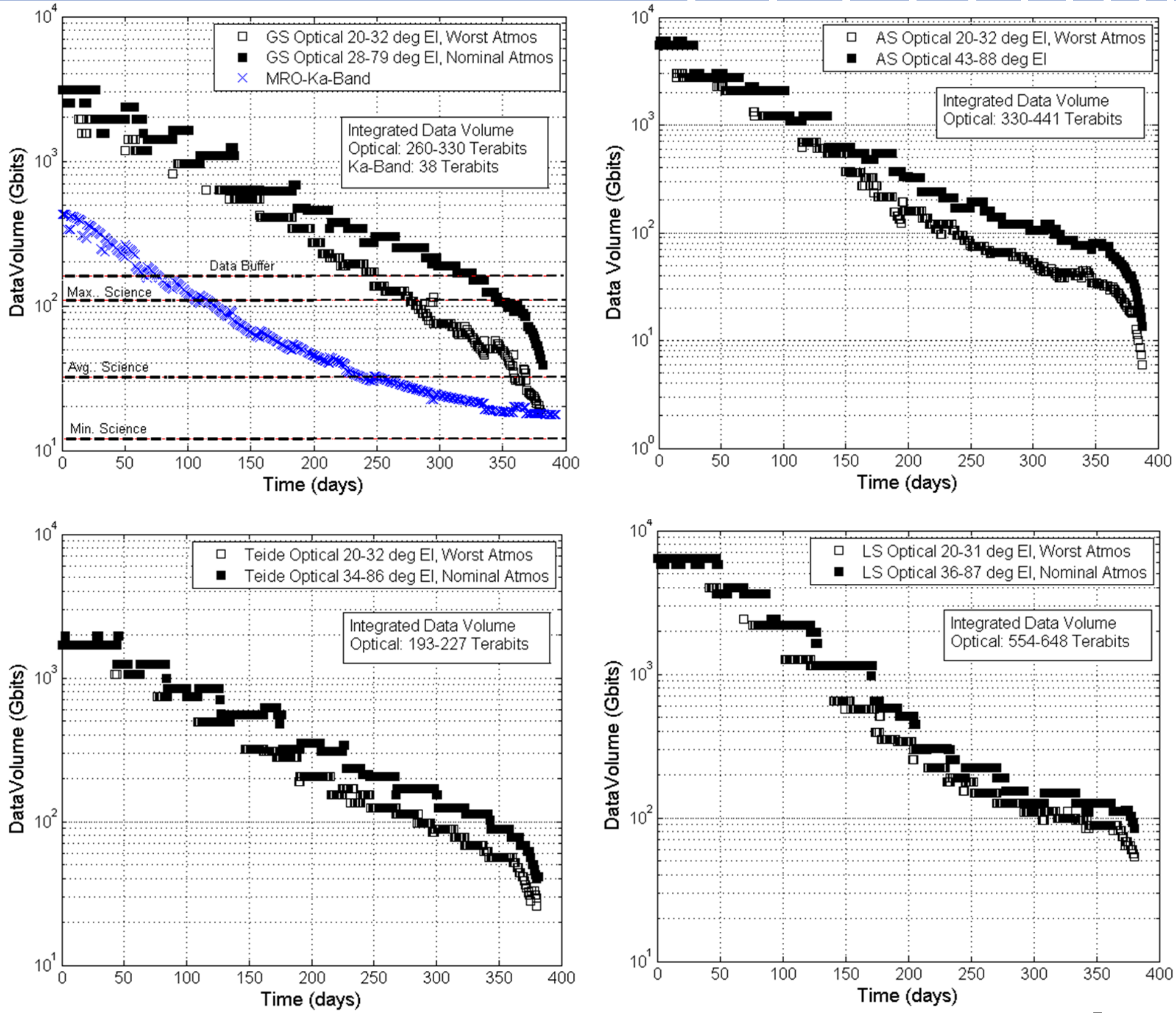
	Goldstone (GS)	Alice Springs (AS)	Teide (T)	La Silla (LS)
Fractional CFLOS Single Site	0.66	0.58	0.39	0.81
2-site availability with LS	0.94		0.88	
2-site availability with GS		0.86	0.79	
3-Site Availability with GS & T				0.96

Ref: *Evaluation of deep-space laser communication under different mission scenarios*, A. Biswas, S. Piazzolla, B. Moision, D. Lisman, *SPIE Free Space Laser Communication Technologies XXIV*, Jan 26, 2011

DATA VOLUME RETURN AT FOUR SITES

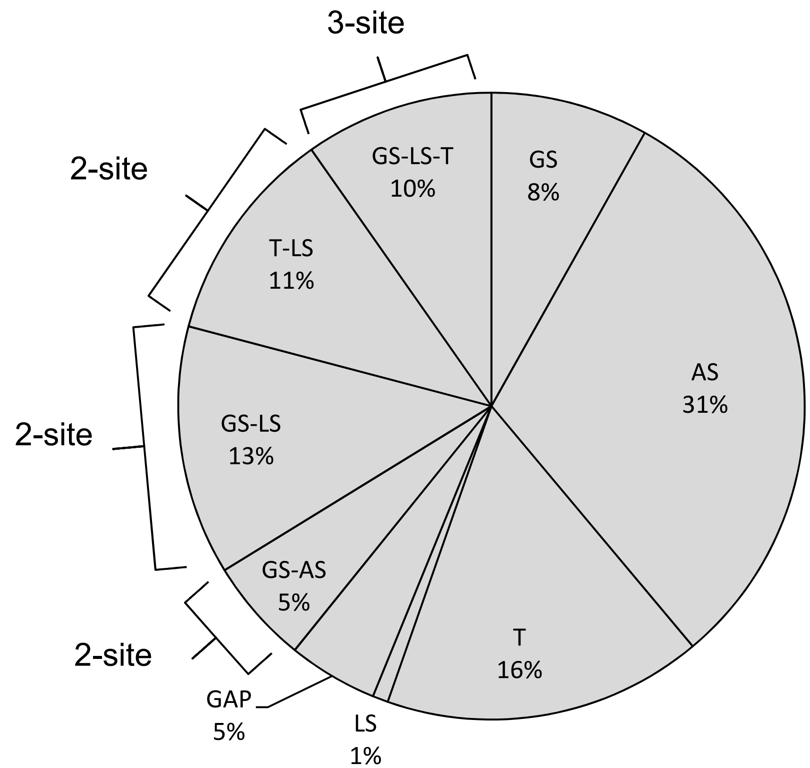
Jet Propulsion Laboratory
California Institute of Technology

- Data rate supported at each site calculated for each pass
- Data volume computed (pass duration x data rate x CFLOS)
- Comparison with Ka-band only at GDSCC
  - Optical shows 6.8-8.7 times better total data volume return than Ka-band over synodic period—including weather



MULTI-SITE NETWORK

- Data-volumes were estimated for each ground station site for ½ synodic period (see previous slide)
  - To first approximation, assume second ½ of synodic period is mirror image
- If single station is in view, then use it for downlink
- Allow choice of stations when there is overlap hence increasing data volume
  - Range in table accounts for picking best and worst possible data return depending upon whether cloudy or not
- Four sites result in 95% contact time—5% gap for low SPE



Percent of synodic period during which each station or combination of stations is in view

	Single-Site (Tbits)	4-site Ground Network (Tbits)
GS	260-329	856-1374
AS	330-441	
T	193-227	
LS	554-648	

EXTENSION OF DATA VOLUME ANALYSIS

- Perform multi-site analysis of data volume return for Ka-band including weather
  - Assume GDSCC, MDSCC & CDSCC
- Recalculate optical multi-site data volume return
  - Start with data rate files that were used for computing optical data return
  - Apply NGC CFLOS “mask” to each file
  - Compute multi-site data return
- Compare

SIMPLIFIED/REDEFINED PDT FOR DEEP SPACE?

- Use a redefined PDT (may want to call it something else) that doesn't require the data rate calculations
- Our ~10X data return assumes ~10X data rate over the same number of passes as RF
- Pick some number, N, for the total duration of passes per day/week/month—assumed to be equivalent to Ka-band
- PDT is now defined as the number of CFLOS hours divided by N hours—though PDT never greater than 1
- Plot vs number of optical stations and variation of N

GOING FORWARD

- Continue to refine "algorithms"
- Consider details of implementation
  - How to select station when multiple in view
  - Scheduling of multiple missions
- Get feedback from deep space end-to-end information systems (EEIS) experts

BACKUP

ORBITAL DISCUSSION-1

- Mars goes full orbit around Sun in ~687 days
- One Mars cycle relative to Earth (synodic period) ~780 days
- Symmetric--can just look at 390 days & multiply by 2
- Elevation angles to Mars from Earth vary with Earth seasons and Mars's movement off the ecliptic plane

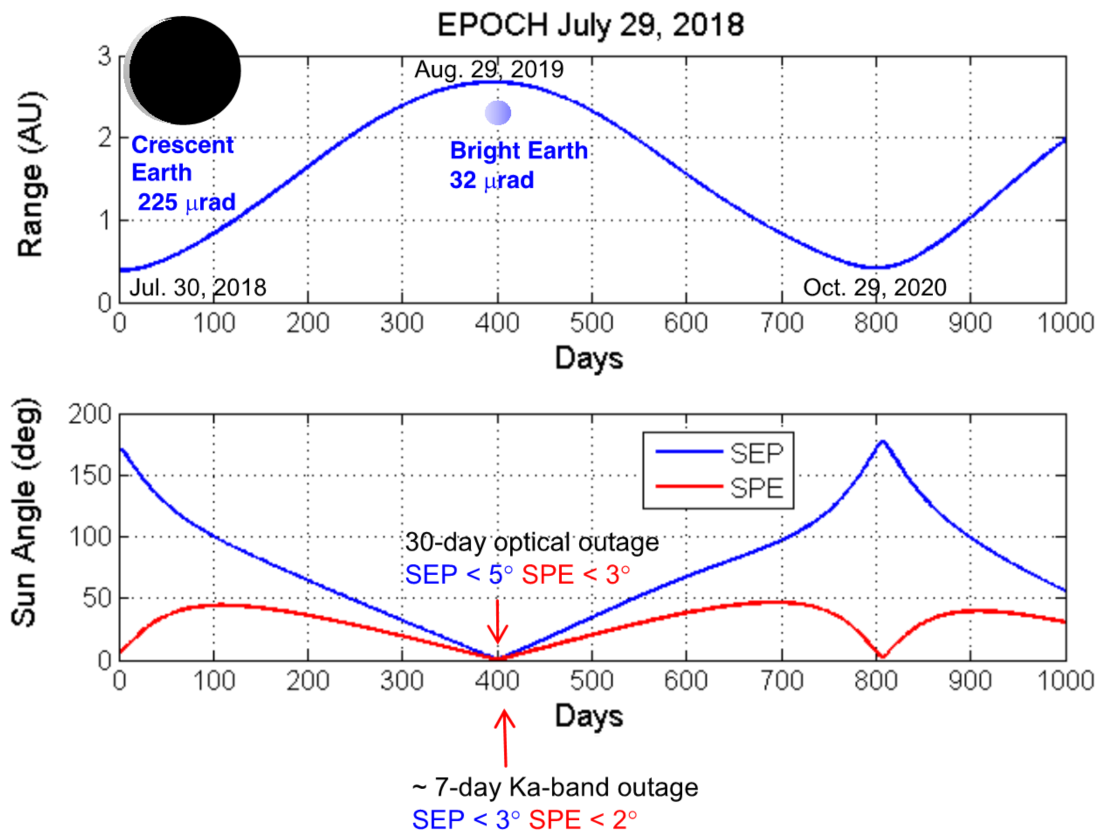
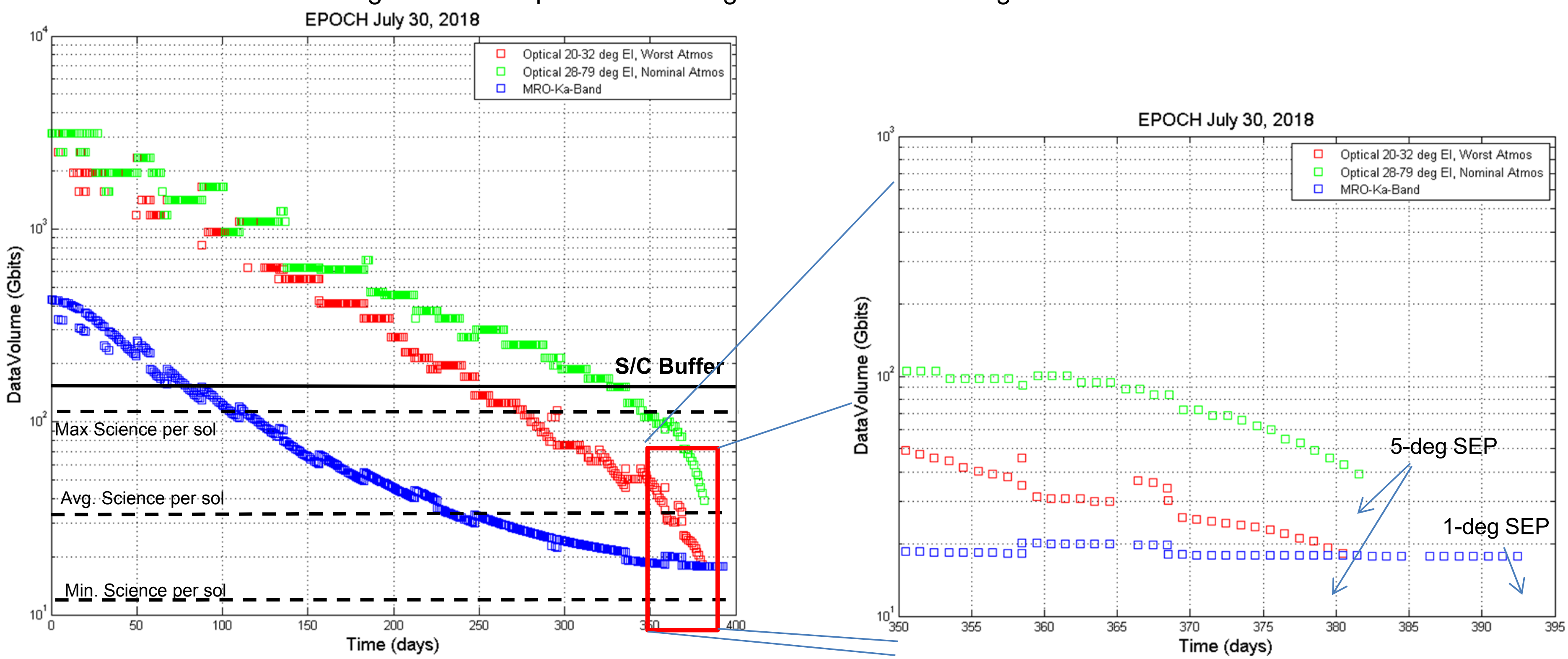


Figure 38: Range and Sun angle variations for Mars

INTEGRATED DATA VOLUMES GDSCC
(5-DEG SEP LIMIT FOR OPTICAL EXPLICITLY INCLUDED)

Jet Propulsion Laboratory
California Institute of Technology

- **Integrated data volume (Gbits) over half of synodic period with 66% average CFLOS and 90% Ka-band availability at GDSCC**
  - Upper bound for optical 3.3×10^5
  - Lower bound for optical 2.6×10^5
  - Ka-band 3.8×10^4
- **Ka-band data volume over duration when optical is not operating, i.e. < 5° SEP**
  - 196 Gbits over 11 days (note this duration and volume will be doubled as Mars crosses Sun)
    - Assuming no Ka-band performance degradation down to 1-deg SEP



Note that at closest approach SPE>3º so no outage

WHAT ABOUT PDT?

- PDT is not a measure normally used in deep space
- Even so, analysis does show value of multiple sites--good description in text
- To compute modified PDT to account for range variation
  - Provide data rate files as in Fig 42 for all sites over period—resources not immediately available to do this
  - Provide buffer scaling algorithm, e.g., Buffer size on day *n*=Max buffer size*(average data rate on day *n)*/(max data rate)
- To compute data volume over synodic period
  - Provide data rate files as in Fig 42 for all sites over period
  - Compute total data transferred as function of number of sites & CFLOS
  - Ideally would average over integer multiple of synodic period